# BMAT Section 2 National Curriculum Coverage

This document outlines all topics that might be tested in Section 2 of the BMAT. It is compiled from sections of the National Curriculum for Double Science and Higher Maths at Key Stages 3 and 4. This version of the National Curriculum was taught up until 2006.

# Sc2 Life processes and living things (Biology)

## Science Key Stage 3

**1: Cells and cell functions**
Students should be taught:
a) that animal cells can form tissues, and tissues can form organs
c) ways in which some cells, including ciliated epithelial cells, sperm, ova and root hair cells, are adapted to their functions
d) that fertilisation in humans is the fusion of a male and a female cell
e) to relate cells and cell functions to life processes in a variety of organisms.

**2: Humans as organisms**
Students should be taught:
**Nutrition**
a) about the need for a balanced diet containing carbohydrates, proteins, fats, minerals, vitamins, fibre and water, and about foods that are sources of these
b) the principles of digestion, including the role of enzymes in breaking down large molecules into smaller ones
c) that the products of digestion are absorbed into the bloodstream and transported throughout the body, and that waste material is egested
d) that food is used as a fuel during respiration to maintain the body's activity and as a raw material for growth and repair
**Movement**
e) the role of the skeleton and joints and the principle of antagonistic muscle pairs [for example, biceps and triceps] in movement
**Reproduction**
f) about the physical and emotional changes that take place during adolescence
g) about the human reproductive system, including the menstrual cycle and fertilisation
h) how the fetus develops in the uterus, including the role of the placenta
**Breathing**
i) the role of lung structure in gas exchange, including the effect of smoking
**Respiration**
j) that aerobic respiration involves a reaction in cells between oxygen and food, in which glucose is broken down into carbon dioxide and water
k) to summarise aerobic respiration in a word equation
l) that the reactants and products of respiration are transported throughout the body in the bloodstream
**Health**
m) that the abuse of alcohol, solvents, and other drugs affects health
n) how the growth and reproduction of bacteria and the replication of viruses can affect health, and how the body's natural defences may be enhanced by immunisation and medicines.

**4: Variation, classification and inheritance**
Students should be taught:
**Variation**
a) about environmental and inherited causes of variation within a species
**Classification**
b) to classify living things into the major taxonomic groups
**Inheritance**
c) that selective breeding can lead to new varieties.

**5: Living things in their environment**
Students should be taught:
**Adaptation and competition**
a) about ways in which living things and the environment can be protected, and the importance of sustainable development
b) that habitats support a diversity of plants and animals that are interdependent
c) how some organisms are adapted to survive daily and seasonal changes in their habitats
d) how predation and competition for resources affect the size of populations [for example, bacteria, growth of vegetation]
**Feeding relationships**
e) about food webs composed of several food chains, and how food chains can be quantified using pyramids of numbers
f) how toxic materials can accumulate in food chains.

## Double science Key Stage 4

**1: Cell activity**
Students should be taught:
b) how substances enter and leave cells through the cell membrane by diffusion, osmosis and active transport
c) that the nucleus contains chromosomes that carry the genes
d) how cells divide by mitosis during growth, and by meiosis to produce gametes
e) to relate ways in which animals function as organisms to cell structure and activity.

**2: Humans as organisms**
Students should be taught:
**Nutrition**
a) the processes of digestion, including the function of organs and the role of enzymes, stomach acid and biles
**Circulation**
b) the structure of the human circulatory system, including the composition and functions of blood
c) that there is an exchange of substances between capillaries and tissues
**Breathing**
d) how the structure of the thorax enables ventilation of the lungs
**Respiration**
e) that respiration may be either aerobic or anaerobic, depending on the availability of oxygen
f) that an 'oxygen debt' may occur in muscle during vigorous exercise
**Nervous system**
g) the pathway taken by impulses in response to a variety of stimuli
h) how the reflex arc makes rapid response to a stimulus possible
i) how the eye functions in response to light
**Hormones**
j) the way in which hormonal control occurs, including the effects of insulin and sex hormones
k) some medical uses of hormones, including the control and promotion of fertility and the treatment of diabetes

**Homeostasis**
l) the importance of maintaining a constant internal environment
m) how waste products of body functions are removed by the lungs and kidneys
n) how the kidneys regulate the water content of the body
o) how humans maintain a constant body temperature
**Health**
p) the defence mechanisms of the body, including the role of the skin, blood and mucous membranes of the respiratory tract
q) the effects of solvents, alcohol, tobacco and other drugs on body functions.

**4: Variation, inheritance and evolution**
Students should be taught:
**Variation**
a) how variation arises from genetic causes, environmental causes, and a combination of both
b) that sexual reproduction is a source of genetic variation, while asexual reproduction produces clones
c) that mutation is a source of genetic variation and has a number of causes
**Inheritance**
d) how sex is determined in humans
e) the mechanism of monohybrid inheritance where there are dominant and recessive alleles
f) about mechanisms by which some diseases are inherited
g) that the gene is a section of DNA
h) the basic principles of cloning, selective breeding and genetic engineering
**Evolution**
i) that the fossil record is evidence for evolution
j) how variation and selection may lead to evolution or to extinction

**5: Living things and their environment**
Students should be taught:
**Adaptation and competition**
a) how the distribution and relative abundance of organisms in habitats can be explained using ideas of interdependence, adaptation, competition and predation
b) how the impact of humans on the environment depends on social and economic factors, including population size, industrial processes and levels of consumption and waste
c) about the importance of sustainable development
**Energy and nutrient transfer**
d) how to describe food chains quantitatively using pyramids of biomass
e) how energy is transferred through an ecosystem
f) the role of microbes and other organisms in the decomposition of organic materials and in the cycling of carbon and nitrogen
g) how food production and distribution systems can be managed to improve the efficiency of energy transfers.

# Sc3 Materials and their properties (Chemistry)

## Science Key Stage 3

**1: Classifying materials**
Students should be taught:
**Solids, liquids and gases**
a) how materials can be characterised by melting point, boiling point and density
b) how the particle theory of matter can be used to explain the properties of solids, liquids and gases, including changes of state, gas pressure and diffusion
**Elements, compounds and mixtures**
c) that the elements are shown in the periodic table and consist of atoms, which can be represented by symbols
d) how elements vary widely in their physical properties, including appearance, state at room temperature, magnetic properties and thermal and electrical conductivity, and how these properties can be used to classify elements as metals or non-metals
e) how elements combine through chemical reactions to form compounds [for example, water, carbon dioxide, magnesium oxide, sodium chloride, most minerals] with a definite composition
f) to represent compounds by formulae and to summarise reactions by word equations
g) that mixtures [for example, air, sea water and most rocks] are composed of constituents that are not combined
h) how to separate mixtures into their constituents using distillation, chromatography and other appropriate methods.

**2: Changing materials**
Students should be taught:
**Physical changes**
a) that when physical changes [for example, changes of state, formation of solutions] take place, mass is conserved
b) about the variation of solubility with temperature, the formation of saturated solutions, and the differences in solubility of solutes in different solvents
c) to relate changes of state to energy transfers
**Geological changes**
d) how forces generated by expansion, contraction and the freezing of water can lead to the physical weathering of rocks
e) about the formation of rocks by processes that take place over different timescales, and that the mode of formation determines their texture and the minerals they contain
f) how igneous rocks are formed by the cooling of magma, sedimentary rocks by processes including the deposition of rock fragments or organic material, or as a result of evaporation, and metamorphic rocks by the action of heat and pressure on existing rocks
**Chemical reactions**
g) how mass is conserved when chemical reactions take place because the same atoms are present, although combined in different ways
h) that virtually all materials, including those in living systems, are made through chemical reactions, and to recognise the importance of chemical change in everyday situations [for example, ripening fruit, setting superglue, cooking food]
i) about possible effects of burning fossil fuels on the environment [for example, production of acid rain, carbon dioxide and solid particles] and how these effects can be minimised.

**3: Patterns of behaviour**
Students should be taught:
**Metals**
a) how metals react with oxygen, water, acids and oxides of other metals, and what the products of these reactions are
b) about the displacement reactions that take place between metals and solutions of salts of other metals
c) how a reactivity series of metals can be determined by considering these reactions, and used to make predictions about other reactions
**Acids and bases**
d) to use indicators to classify solutions as acidic, neutral or alkaline, and to use the pH scale as a measure of the acidity of a solution
e) how metals and bases, including carbonates, react with acids and what the products of these reactions are
f) about some everyday applications of neutralisation [for example, the treatment of indigestion, the treatment of acid soil, the manufacture of fertiliser]
g) how acids in the environment can lead to corrosion of some metals and chemical weathering of rock [for example, limestone]
h) to identify patterns in chemical reactions.

## Double science Key Stage 4

**1: Classifying materials**
Students should be taught
**Atomic structure**
a) that atoms consist of nuclei and electrons
b) the charges and relative masses of protons, neutrons and electrons
c) about mass number, atomic number and isotopes
d) about a model of the way electrons are arranged in atoms
e) how the reactions of elements depend on the arrangement of electrons in their atoms
**Bonding**
f) that new substances are formed when atoms combine
g) that chemical bonding can be explained in terms of the transfer or sharing of electrons
h) how ions are formed when atoms gain or lose electrons and how giant ionic lattices are held together by the attraction between oppositely charged ions
i) how covalent bonds are formed when atoms share electrons
j) that substances with covalent bonds may form simple molecular structures or giant structures
k) ways in which the physical properties of some substances with giant structures differ from those with simple molecular structures.

**2: Changing materials**
Students should be taught
**Useful products from organic sources**
a) how the mixture of substances in crude oil, most of which are hydrocarbons, can be separated by fractional distillation
b) the use of some of the products from crude oil distillation as fuels
c) the products of burning hydrocarbons
d) that alkanes are saturated hydrocarbons, and alkenes are unsaturated hydrocarbons
e) how addition polymers can be formed from the products of crude oil by cracking and polymerisation
f) some uses of addition polymers

**Quantitative chemistry**
n) to represent chemical reactions by balanced symbol equations and to use these to predict reacting quantities
o) to determine the formulae of simple compounds from reacting masses.

**3: Patterns of behaviour**
Students should be taught
**The periodic table**
a) that there are approximately 100 elements and that all materials are composed of one or more of these
b) that the periodic table shows all the elements, arranged in order of ascending atomic number
c) the connection between the arrangement of outer electrons and the position of an element in the periodic table
d) that elements in the same group of the periodic table have similar properties
e) how the properties of elements change gradually from the top to the bottom of a group
f) the properties and uses of the noble gases
g) the properties and reactions of the alkali metals
h) the properties, reactions and uses of the halogens
i) about similarities between transition metals and about the characteristic properties of their compounds
j) some uses of transition metals
**Chemical reactions**
k) about different types of chemical reaction, including neutralisation, oxidation, reduction and thermal decomposition, and examples of how these are used to make new materials
l) to recognise patterns in chemical reactions and use these to make predictions
m) about ways in which knowledge about chemical reactions is applied when new substances are made
**Rates of reaction**
n) about the great variation in the rates at which different reactions take place
o) how the rates of reactions can be altered by varying temperature or concentration, or by changing the surface area of a solid reactant, or by adding a catalyst
p) how the rates of many reactions depend on the frequency and energy of collisions between particles
**Reactions involving enzymes**
q) about the effect of temperature on the rates of enzyme-catalysed reactions and their dependence on pH
r) how enzymes may be used in biotechnology
**Reversible reactions**
s) about manufacturing processes based on reversible reactions, and how the yield of these depends on the conditions
**Energy transfer in reactions**
t) that changes of temperature often accompany reactions
u) that reactions can be exothermic or endothermic
v) how making and breaking chemical bonds in chemical reactions involves energy transfers.

# Sc4 Physical processes (Physics)

## Science Key Stage 3

**1: Electricity and magnetism**
Students should be taught
**Circuits**
a) how to design and construct series and parallel circuits, and how to measure current and voltage
b) that the current in a series circuit depends on the number of cells and the number and nature of other components and that current is not 'used up' by components
c) that energy is transferred from batteries and other sources to other components in electrical circuits
**Magnetic fields**
d) about magnetic fields as regions of space where magnetic materials experience forces, and that like magnetic poles repel and unlike poles attract
**Electromagnets**
e) that a current in a coil produces a magnetic field pattern similar to that of a bar magnet
f) how electromagnets are constructed and used in devices [for example, relays, lifting magnets].

**2: Forces and motion**
Students should be taught
**Force and linear motion**
a) how to determine the speed of a moving object and to use the quantitative relationship between speed, distance and time
b) that the weight of an object on Earth is the result of the gravitational attraction between its mass and that of the Earth
c) that unbalanced forces change the speed or direction of movement of objects and that balanced forces produce no change in the movement of an object
d) ways in which frictional forces, including air resistance, affect motion [for example, streamlining cars, friction between tyre and road]
**Force and rotation**
e) that forces can cause objects to turn about a pivot
f) the principle of moments and its application to situations involving one pivot
**Force and pressure**
g) the quantitative relationship between force, area and pressure and its application [for example, the use of skis and snowboards, the effect of sharp blades, hydraulic brakes].

**3: Light and sound**
Students should be taught
**The behaviour of light**
a) that light travels in a straight line at a finite speed in a uniform medium
b) that non-luminous objects are seen because light scattered from them enters the eye
c) how light is reflected at plane surfaces
d) how light is refracted at the boundary between two different materials
e) that white light can be dispersed to give a range of colours
f) the effect of colour filters on white light and how coloured objects appear in white light and in other colours of light
**Hearing**
g) that sound causes the eardrum to vibrate and that different people have different audible ranges

h) some effects of loud sounds on the ear [for example, temporary deafness]

**Vibration and sound**

i) that light can travel through a vacuum but sound cannot, and that light travels much faster than sound

j) the relationship between the loudness of a sound and the amplitude of the vibration causing it

k) the relationship between the pitch of a sound and the frequency of vibration causing it.

**5: Energy resources and energy transfer**

Students should be taught

**Energy resources**

a) about the variety of energy resources, including oil, gas, coal, biomass, food, wind, waves and batteries, and the distinction between renewable and non-renewable resources

b) about the Sun as the ultimate source of most of the Earth's energy resources and to relate this to how coal, oil and gas are formed

c) that electricity is generated by means of a variety of energy resources

**Conservation of energy**

d) the distinction between temperature and heat, and that differences in temperature can lead to transfer of energy

e) ways in which energy can be usefully transferred and stored

f) how energy is transferred by the movement of particles in conduction, convection and evaporation, and that energy is transferred directly by radiation

g) that although energy is always conserved, it may be dissipated, reducing its availability as a resource.

## Double Science Key Stage 4

**1: Electricity**

Students should be taught

**Circuits**

a) that resistors are heated when charge flows through them

b) the qualitative effect of changing resistance on the current in a circuit

c) the quantitative relationship between resistance, voltage and current

d) how current varies with voltage in a range of devices [for example, resistors, filament bulbs, diodes, light dependent resistors (LDRs) and thermistors]

e) that voltage is the energy transferred per unit charge

f) the quantitative relationship between power, voltage and current

**Mains electricity**

g) the difference between direct current (dc) and alternating current (ac)

h) the functions of the live, neutral and earth wires in the domestic mains supply, and the use of insulation, earthing, fuses and circuit breakers to protect users of electrical equipment

i) how electrical heating is used in a variety of ways in domestic contexts

j) how measurements of energy transferred are used to calculate the costs of using common domestic appliances

**Electric charge**

k) how an insulating material can be charged by friction

l) about forces of attraction between positive and negative charges, and forces of repulsion between like charges

m) about common electrostatic phenomena, in terms of the movement of electrons

n) the uses and potential dangers of electrostatic charges generated in everyday situations [for example, in photocopiers and inkjet printers]

o) the quantitative relationship between steady current, charge and time

p) about electric current as the flow of charge carried by free electrons in metals or ions during electrolysis.

**2: Forces and motion**

Students should be taught

**Force and acceleration**

a) how distance, time and speed can be determined and represented graphically
b) about factors affecting vehicle stopping distances
c) the difference between speed and velocity
d) that acceleration is change in velocity per unit time
e) that balanced forces do not alter the velocity of a moving object
f) the quantitative relationship between force, mass and acceleration
g) that when two bodies interact, the forces they exert on each other are equal and opposite

**Force and non-uniform**

h) how the forces acting on falling objects change with velocity
i) why falling objects may reach a terminal velocity.

**3: Waves**

Students should be taught

**Characteristics of waves**

a) about the reflection, refraction and diffraction of waves, including light and sound as examples of transverse and longitudinal waves
b) the meaning of frequency, wavelength and amplitude of a wave
c) the quantitative relationship between the speed, frequency and wavelength of a wave
d) that waves transfer energy without transferring matter

**The electromagnetic spectrum**

e) that the electromagnetic spectrum includes radio waves, microwaves, infrared, visible light, ultraviolet waves, X-rays and gamma rays
f) some ways in which microwaves, infrared and ultraviolet waves are used and the potential dangers of these
g) some uses of X-rays and gamma rays in medicine
h) how information can be transmitted along optical fibres
i) that radio waves, microwaves, infrared and visible light carry information over large and small distances, including global transmission via satellites
j) about ways in which reflection, refraction and diffraction affect communication
k) the difference between analogue and digital signals and how more information can be transmitted

**Sound and ultrasound**

l) about sound and ultrasound waves, and some medical and other uses of ultrasound

**5: Energy resources and energy transfer**

Students should be taught

**Energy transfer**

a) how insulation is used to reduce transfer of energy from hotter to colder objects
b) about the efficient use of energy, the need for economical use of energy resources, and the environmental implications of generating energy

**Work, power and energy**

c) the quantitative relationship between force and work
d) to calculate power in terms of the rate of working or of transferring energy
e) to calculate kinetic energy and potential energy

**Electromagnetic effects**

f) that a force is exerted on a current-carrying wire in a magnetic field and the application of this effect in simple electric motors
g) that a voltage is induced when a conductor cuts magnetic field lines and when the magnetic field through a coil changes

h) how simple ac generators and transformers work
i) the quantitative relationship between the voltages across the coils in a transformer and the numbers of turns in them
j) how energy is transferred from power stations to consumers.

**6: Radioactivity**
Students should be taught
a) that radioactivity arises from the breakdown of an unstable nucleus
b) about some sources of the ionising radiation found in all environments
c) the characteristics of alpha and beta particles and of gamma radiation
d) the meaning of the term 'half-life'
e) the beneficial and harmful effects of ionising radiation on matter and living organisms
f) some uses of radioactivity, including radioactive dating of rocks.

# Maths Key Stage 4 Higher

## Ma2 Number and algebra

**1: Using and applying number and algebra**
Students should be taught to:
a) select and use appropriate and efficient techniques and strategies to solve problems of increasing complexity, involving numerical and algebraic manipulation
b) identify what further information may be required in order to pursue a particular line of enquiry and give reasons for following or rejecting particular approaches
c) break down a complex calculation into simpler steps before attempting a solution and justify their choice of methods
d) make mental estimates of the answers to calculations; present answers to sensible levels of accuracy; understand how errors are compounded in certain calculations
**Communicating**
e) discuss their work and explain their reasoning using an increasing range of mathematical language and notation
f) use a variety of strategies and diagrams for establishing algebraic or graphical representations of a problem and its solution; move from one form of representation to another to get different perspectives on the problem
g) present and interpret solutions in the context of the original problem
h) use notation and symbols correctly and consistently within a given problem
i) examine critically, improve, then justify their choice of mathematical presentation; present a concise, reasoned argument
**Reasoning**
explore, identify, and use pattern and symmetry in algebraic contexts, investigating whether a particular case may be generalised further and understand the importance of a counter-example; identify exceptional cases when solving problems
understand the difference between a practical demonstration and a proof
show step-by-step deduction in solving a problem; derive proofs using short chains of deductive reasoning
recognise the significance of stating constraints and assumptions when deducing results; recognise the limitations of any assumptions that are made and the effect that varying the assumptions may have on the solution to a problem.

**2: Numbers and the number system**
Students should be taught to:
a) use their previous understanding of integers and place value to deal with arbitrarily large positive numbers and round them to a given power of 10; understand and use negative integers both as positions and translations on a number line; order integers; use the concepts and vocabulary of factor (divisor), multiple, common factor, highest common factor, least common multiple, prime number and prime factor decomposition
**Powers and roots**
b) use the terms square, positive square root, negative square root, cube and cube root; use index notation [for example, $8^2$, $8^{-\frac{2}{3}}$] and index laws for multiplication and division of integer powers; use standard index form, expressed in conventional notation and on a calculator display
**Fractions**
c) understand equivalent fractions, simplifying a fraction by cancelling all common factors; order fractions by rewriting them with a common denominator

**Decimals**

d) recognise that each terminating decimal is a fraction [for example, $0.137 = \frac{137}{1000}$]; recognise that recurring decimals are exact fractions, and that some exact fractions are recurring decimals [for example, $\frac{1}{7}$ = 0.142857142857.....]; order decimals

**Percentages**

e) understand that 'percentage' means 'number of parts per 100', and interpret percentage as the operator 'so many hundredths of' [for example, 10% means 10 parts per 100 and 15% of Y means $\frac{15}{100} \times$ Y]

**Ratio**

f) use ratio notation, including reduction to its simplest form and its various links to fraction notation.

**3: Calculations**

Students should be taught to:

a) multiply or divide any number by powers of 10, and any positive number by a number between 0 and 1; find the prime factor decomposition of positive integers; understand 'reciprocal' as multiplicative inverse, knowing that any non-zero number multiplied by its reciprocal is 1 (and that zero has no reciprocal, because division by zero is not defined); multiply and divide by a negative number; use index laws to simplify and calculate the value of numerical expressions involving multiplication and division of integer, fractional and negative powers; use inverse operations, understanding that the inverse operation of raising a positive number to power *n* is raising the result of this operation to power $\frac{1}{n}$

b) use brackets and the hierarchy of operations

c) calculate a given fraction of a given quantity, expressing the answer as a fraction; express a given number as a fraction of another; add and subtract fractions by writing them with a common denominator; perform short division to convert a simple fraction to a decimal; distinguish between fractions with denominators that have only prime factors of 2 and 5 (which are represented by terminating decimals), and other fractions (which are represented by recurring decimals); convert a recurring decimal to a fraction [for example, 0.142857142857... = $\frac{1}{7}$]

d) understand and use unit fractions as multiplicative inverses [for example, by thinking of multiplication by $\frac{1}{5}$ as division by 5, or multiplication by $\frac{6}{7}$ as multiplication by 6 followed by division by 7 (or vice versa)]; multiply and divide a given fraction by an integer, by a unit fraction and by a general fraction

e) convert simple fractions of a whole to percentages of the whole and vice versa; then understand the multiplicative nature of percentages as operators [for example, a 15% increase in value Y, followed by a 15% decrease is calculated as $1.15 \times 0.85 \times$ Y]; calculate an original amount when given the transformed amount after a percentage change; reverse percentage problems [for example, given that a meal in a restaurant costs £36 with VAT at 17.5%, its price before VAT is calculated as £$\frac{36}{1.175}$]

f) divide a quantity in a given ratio

**Mental methods**

g) recall integer squares from 2 × 2 to 15 × 15 and the corresponding square roots, the cubes of 2, 3, 4, 5 and 10, the fact that $n^0 = 1$ and $n^{-1} = \frac{1}{n}$ for positive integers *n* [for example, $10^0 = 1$; $9^{-1} = \frac{1}{9}$], the corresponding rule for negative numbers [for example, $5^{-2} = \frac{1}{5^2} = \frac{1}{25}$], $n^{\frac{1}{2}} = \sqrt{n}$ and $n^{\frac{1}{3}} = \sqrt[3]{n}$ for any positive number *n* [for example, $25^{\frac{1}{2}} = 5$ and $64^{\frac{1}{3}} = 4$]

h) round to a given number of significant figures; develop a range of strategies for mental calculation; derive unknown facts from those they know; convert between ordinary and standard index form representations [for example, $0.1234 = 1.234^{-1}$], converting to standard index form to make sensible estimates for calculations involving multiplication and/or division

**Written methods**

i) use efficient methods to calculate with fractions, including cancelling common factors before carrying out the calculation, recognising that in many cases only a fraction can express the exact answer

j) solve percentage problems, including percentage increase and decrease [for example, simple interest, VAT, annual rate of inflation]; and reverse percentages

k) represent repeated proportional change using a multiplier raised to a power [for example, compound interest]

l) calculate an unknown quantity from quantities that vary in direct or inverse proportion

m) calculate with standard index form [for example, $2.4 \times 10^7 \times 5 \times 10^3 = 12 \times 10^{10} = 1.2 \times 10^{11}$, $(2.4 \times 10^7) \div (5 \times 10^3) = 4.8 \times 10^3$]

n) use surds and $\pi$ in exact calculations, without a calculator; rationalise a denominator such as $\frac{1}{\sqrt{3}} = \frac{\sqrt{3}}{3}$

**Calculator methods**

o) use calculators effectively and efficiently, knowing how to enter complex calculations; use an extended range of function keys, including trigonometrical and statistical functions relevant across this programme of study

p) understand the calculator display, knowing when to interpret the display, when the display has been rounded by the calculator, and not to round during the intermediate steps of a calculation

q) use calculators, or written methods, to calculate the upper and lower bounds of calculations, particularly when working with measurements

r) use standard index form display and how to enter numbers in standard index form

s) use calculators for reverse percentage calculations by doing an appropriate division

t) use calculators to explore exponential growth and decay [for example, in science or geography], using a multiplier and the power key.

**4: Solving numerical problems**

Students should be taught to:

a) draw on their knowledge of operations and inverse operations (including powers and roots), and of methods of simplification (including factorisation and the use of the commutative, associative and distributive laws of addition, multiplication and factorisation) in order to select and use suitable strategies and techniques to solve problems and word problems, including those involving ratio and proportion, repeated proportional change, fractions, percentages and reverse percentages, inverse proportion, surds, measures and conversion between measures, and compound measures defined within a particular situation

b) check and estimate answers to problems; select and justify appropriate degrees of accuracy for answers to problems; recognise limitations on the accuracy of data and measurements.

**5: Equations, formulae and identities**

Students should be taught to:

a)distinguish the different roles played by letter symbols in algebra, using the correct notational conventions for multiplying or dividing by a given number, and knowing that letter symbols represent definite unknown numbers in equations [for example, $x^2 + 1 = 82$], defined quantities or variables in formula [for example, V = IR], general, unspecified and independent numbers in identities [for example, $(x + 1)^2 = x^2 + 2x + 1$ for all $x$], and in functions they define new expressions or quantities by referring to known quantities [for example, $y = 2 - 7x$; $f(x) = x^3$; $y = m$ with $x \neq 0$]

b) understand that the transformation of algebraic entities obeys and generalises the well-defined rules of generalised arithmetic [for example, $a(b + c) = ab + ac$]; expand the product of two linear expressions [for example, $(x + 1)(x + 2) = x^2 + 3x + 2$]; manipulate algebraic expressions by collecting like terms, multiplying a single term over a bracket, taking out common factors [for example, $9x - 3 = 3(3x - 1)$], factorising quadratic expressions including the difference of two squares [for example, $x^2 - 9 = (x + 3)(x - 3)$]and cancelling common factors in rational expressions [for example, $(2(x + 1)^2 \div (x + 1) = 2(x + 1)$]

c) know the meaning of and use the words 'equation', 'formula', 'identity' and 'expression'

**Index notation**

d) use index notation for simple integer powers, and simple instances of index laws [for example, $x^3 \times x^2 = x^5$; $\frac{x^2}{x^3} = x^{-1}$; $(x^2)^3 = x^6$]; substitute positive and negative numbers into expressions such as $3x^2 + 4$ and $2x^3$

**Equations**

e) set up simple equations [for example, find the angle $a$ in a triangle with angles $a$, $a + 10$, $a + 20$]; solve simple equations [for example, $5x = 7$; $11 - 4x = 2$; $3(2x + 1) = 8$; $2(1 - x) = 6(2 + x)$; $4x^2 = 49$; $3 = \frac{12}{x}$] by using inverse operations or by transforming both sides in the same way

**Linear equations**

f) solve linear equations in one unknown, with integer or fractional coefficients, in which the unknown appears on either side or on both sides of the equation; solve linear equations that require prior simplification of brackets, including those that have negative signs occurring anywhere in the equation, and those with a negative solution

**Formulae**

g) use formulae from mathematics and other subjects [for example, for area of a triangle or a parallelogram, area enclosed by a circle, volume of a prism, volume of a cone]; substitute numbers into a formula; change the subject of a formula, including cases where the subject occurs twice, or where a power of the subject appears [for example, find $r$ given that $A = \pi r^2$, find $x$ given $y = mx + c$]; generate a formula [for example, find the perimeter of a rectangle given its area A and the length $l$ of one side]

**Direct and inverse proportion**

h) set up and use equations to solve word and other problems involving direct proportion or inverse proportion [for example, $y \propto x$, $y \propto x^2$, $y \propto \frac{1}{x}$, $y \propto \frac{1}{x^2}$ and relate algebraic solutions to graphical representation of the equations

**Simultaneous linear equations**

i) find the exact solution of two simultaneous equations in two unknowns by eliminating a variable, and interpret the equations as lines and their common solution as the point of intersection
j) solve simple linear inequalities in one variable, and represent the solution set on a number line; solve several linear inequalities in two variables and find the solution set

**Quadratic equations**

k) solve quadratic equations by factorisation, completing the square and using the quadratic formula

**Simultaneous linear and quadratic equations**

l) solve exactly, by elimination of an unknown, two simultaneous equations in two unknowns, one of which is linear in each unknown, and the other is linear in one unknown and quadratic in the other [for example, solve the simultaneous equations $y = 11x - 2$ and $y = 5x^2$], or where the second is of the form $x^2 + y^2 = r^2$

**Numerical methods**

m) use systematic trial and improvement to find approximate solutions of equations where there is no simple analytical method of solving them [for example, $x^3 - x = 900$].

**6: Sequences, functions and graphs**

Students should be taught to:
a) generate common integer sequences (including sequences of odd or even integers, squared integers, powers of 2, powers of 10, triangular numbers); generate terms of a sequence using term-to-term and position-to-term definitions of the sequence; use linear expressions to describe the *n*th term of an arithmetic sequence, justifying its form by reference to the activity or context from which it was generated

**Graphs of linear functions**

b) use conventions for coordinates in the plane; plot points in all four quadrants; recognise (when values are given for *m* and *c*) that equations of the form $y = mx + c$ correspond to straight-line graphs in the coordinate plane; plot graphs of functions in which *y* is given explicitly in terms of *x* (as in $y = 2x + 3$), or implicitly (as in $x + y = 7$)
c) find the gradient of lines given by equations of the form $y = mx + c$ (when values are given for *m* and *c*); understand that the form $y = mx + c$ represents a straight line and that *m* is the gradient of the line, and *c* is the value of the *y* intercept; explore the gradients of parallel lines and lines perpendicular to these lines [for example, know that the lines represented by the equations $y = -5x$ and $y = 3 - 5x$ are parallel, each having gradient (-5) and that the line with equation $y =$ (*x* divided by 5) is perpendicular to these lines and has gradient one-fifth]

**Interpreting graphical information**

d) construct linear functions and plot the corresponding graphs arising from real-life problems; discuss and interpret graphs modelling real situations [for example, distance-time graph for a particle moving with constant speed, the depth of water in a container as it empties, the velocity-time graph for a particle moving with constant acceleration]

**Quadratic functions**

e) generate points and plot graphs of simple quadratic functions [for example, $y = x^2$; $y = 3x^2 + 4$], then more general quadratic functions [for example, $y = x^2 - 2x + 1$]; find approximate solutions of a quadratic equation from the graph of the corresponding quadratic function; find the intersection points of the graphs of a linear and quadratic function, knowing that these are the approximate solutions of the corresponding simultaneous equations representing the linear and quadratic functions

**Other functions**

f) plot graphs of: simple cubic functions [for example, $y = x^3$], the reciprocal function $y = \frac{1}{x}$ with $x \neq 0$, the exponential function $y = k^x$ for integer values of *x* and simple positive values of *k* [for example, $y = 2^x$; $y = (\frac{1}{2})^x$], the circular functions $y = \sin x$ and $y = \cos x$, using a

spreadsheet or graph plotter as well as pencil and paper; recognise the characteristic shapes of all these functions

**Transformation of functions**

g) apply to the graph of $y = f(x)$ the transformations $y = f(x) + a$, $y = f(ax)$, $y = f(x + a)$, $y = af(x)$, for linear, quadratic, sine and cosine functions $f(x)$

**Loci**

h)construct the graphs of simple loci, including the circle $x^2 + y^2 = r^2$ for a circle of radius $r$ centred at the origin of coordinates; find graphically the intersection points of a given straight line with this circle and know that this corresponds to solving the two simultaneous equations representing the line and the circle.

# Ma3 Shape, space & measures

**1: Using and applying shape, space and measures**
Students should be taught to:
a)select the problem-solving strategies to use in geometrical work, and consider and explain the extent to which the selections they made were appropriate
b) select and combine known facts and problem-solving strategies to solve more complex geometrical problems
c) develop and follow alternative lines of enquiry, justifying their decisions to follow or reject particular approaches
**Communicating**
d) communicate mathematically, with emphasis on a critical examination of the presentation and organisation of results, and on effective use of symbols and geometrical diagrams
e) use precise formal language and exact methods for analysing geometrical configurations
**Reasoning**
f) apply mathematical reasoning, progressing from brief mathematical explanations towards full justifications in more complex contexts
g) explore connections in geometry; pose conditional constraints of the type 'If ... then ...'; and ask questions 'What if ...?' or 'Why?'
h) show step-by-step deduction in solving a geometrical problem
i) state constraints and give starting points when making deductions
j) understand the necessary and sufficient conditions under which generalisations, inferences and solutions to geometrical problems remain valid.

**2: Geometrical reasoning**
Students should be taught to:
a) distinguish between lines and line segments; use parallel lines, alternate angles and corresponding angles; understand the consequent properties of parallelograms and a proof that the angle sum of a triangle is 180 degrees; understand a proof that the exterior angle of a triangle is equal to the sum of the interior angles at the other two vertices
b) use angle properties of equilateral, isosceles and right-angled triangles; explain why the angle sum of a quadrilateral is 360 degrees
c) recall the definitions of special types of quadrilateral, including square, rectangle, parallelogram, trapezium and rhombus; classify quadrilaterals by their geometric properties
d) calculate and use the sums of the interior and exterior angles of quadrilaterals, pentagons, hexagons; calculate and use the angles of regular polygons
e) understand and use SSS, SAS, ASA and RHS conditions to prove the congruence of triangles using formal arguments, and to verify standard ruler and compass constructions
f) understand, recall and use Pythagoras' theorem in 2-D, then 3-D problems; investigate the geometry of cuboids including cubes, and shapes made from cuboids, including the use of Pythagoras' theorem to calculate lengths in three dimensions
g) understand similarity of triangles and of other plane figures, and use this to make geometric inferences; understand, recall and use trigonometrical relationships in right-angled triangles, and use these to solve problems, including those involving bearings, then use these relationships in 3-D contexts, including finding the angles between a line and a plane (but not the angle between two planes or between two skew lines); calculate the area of a triangle using $\frac{1}{2}ab\sin C$; draw, sketch and describe the graphs of trigonometric functions for angles of any size, including transformations involving scalings in either or both the $x$ and $y$ directions; use the sine and cosine rules to solve 2-D and 3-D problems

**Properties of circles**

h) recall the definition of a circle and the meaning of related terms, including centre, radius, chord, diameter, circumference, tangent, arc, sector and segment; understand that the tangent at any point on a circle is perpendicular to the radius at that point; understand and use the fact that tangents from an external point are equal in length; explain why the perpendicular from the centre to a chord bisects the chord; understand that inscribed regular polygons can be constructed by equal division of a circle; prove and use the facts that the angle subtended by an arc at the centre of a circle is twice the angle subtended at any point on the circumference, the angle subtended at the circumference by a semicircle is a right angle, that angles in the same segment are equal, and that opposite angles of a cyclic quadrilateral sum to 180 degrees; prove and use the alternate segment theorem

**3-D shapes**

i) use 2-D representations of 3-D shapes and analyse 3-D shapes through 2-D projections and cross-sections, including plan and elevation; solve problems involving surface areas and volumes of prisms, pyramids, cylinders, cones and spheres; solve problems involving more complex shapes and solids, including segments of circles and frustums of cones.

**3: Transformations and coordinates**

Students should be taught to:

a) understand that rotations are specified by a centre and an (anticlockwise) angle; use any point as the centre of rotation; measure the angle of rotation, using right angles, fractions of a turn or degrees; understand that reflections are specified by a (mirror) line; understand that translations are specified by giving a distance and direction (or a vector), and enlargements by a centre and a positive scale factor

**Properties of transformations**

b) recognise and visualise rotations, reflections and translations including reflection symmetry of 2-D and 3-D shapes, and rotation symmetry of 2-D shapes; transform triangles and other 2-D shapes by translation, rotation and reflection and combinations of these transformations; use congruence to show that translations, rotations and reflections preserve length and angle, so that any figure is congruent to its image under any of these transformations; distinguish properties that are preserved under particular transformations

c) recognise, visualise and construct enlargements of objects; understand from this that any two circles and any two squares are mathematically similar, while, in general, two rectangles are not, then use positive fractional and negative scale factors

d) recognise that enlargements preserve angle but not length; identify the scale factor of an enlargement as the ratio of the lengths of any two corresponding line segments; understand the implications of enlargement for perimeter; use and interpret maps and scale drawings; understand the difference between formulae for perimeter, area and volume by considering dimensions; understand and use the effect of enlargement on areas and volumes of shapes and solids

**Coordinates**

e) understand that one coordinate identifies a point on a number line, that two coordinates identify a point in a plane and three coordinates identify a point in space, using the terms '1-D', '2-D' and '3-D'; use axes and coordinates to specify points in all four quadrants; locate points with given coordinates; find the coordinates of points identified by geometrical information; find the coordinates of the midpoint of the line segment AB, given the points A and B, then calculate the length AB

**Vectors**

f) understand and use vector notation; calculate, and represent graphically the sum of two vectors, the difference of two vectors and a scalar multiple of a vector; calculate the resultant of two vectors; understand and use the commutative and associative properties of vector addition; solve simple geometrical problems in 2-D using vector methods.

**4: Measures and construction**

Students should be taught to:

a) use angle measure [for example, use bearings to specify direction]; know that measurements using real numbers depend on the choice of unit; recognise that measurements given to the nearest whole unit may be inaccurate by up to one half in either direction; convert measurements from one unit to another; understand and use compound measures, including speed and density

**Construction**

b) draw approximate constructions of triangles and other 2-D shapes, using a ruler and protractor, given information about side lengths and angles; construct specified cubes, regular tetrahedra, square-based pyramids and other 3-D shapes

c) use straight edge and compasses to do standard constructions including an equilateral triangle with a given side, the midpoint and perpendicular bisector of a line segment, the perpendicular from a point to a line, the perpendicular from a point on a line, and the bisector of an angle

**Mensuration**

d) find the surface area of simple shapes by using the formulae for the areas of triangles and rectangles; find volumes of cuboids, recalling the formula and understanding the connection to counting cubes and how it extends this approach; calculate volumes of right prisms and of shapes made from cubes and cuboids; convert between volume measures including $cm^3$ and $m^3$ ; find circumferences of circles and areas enclosed by circles, recalling relevant formulae; calculate the lengths of arcs and the areas of sectors of circles

**Loci**

e) find loci, both by reasoning and by using ICT to produce shapes and paths [for example, a region bounded by a circle and an intersecting line].

# Ma4 Handling data

**1: Using and applying handling data**

Students should be taught to:

a) carry out each of the four aspects of the handling data cycle to solve problems:

i. specify the problem and plan: formulate questions in terms of the data needed, and consider what inferences can be drawn from the data; decide what data to collect (including sample size and data format) and what statistical analysis is needed)

ii. collect data from a variety of suitable sources, including experiments and surveys, and primary and secondary sources

iii. process and represent the data: turn the raw data into usable information that gives insight into the problem

iv. interpret and discuss the data: answer the initial question by drawing conclusions from the data

b) select the problem-solving strategies to use in statistical work, and monitor their effectiveness (these strategies should address the scale and manageability of the tasks, and should consider whether the mathematics and approach used are delivering the most appropriate solutions)

**Communicating**

c) communicate mathematically, with emphasis on the use of an increasing range of diagrams and related explanatory text, on the selection of their mathematical presentation, explaining its purpose and approach, and on the use of symbols to convey statistical meaning

**Reasoning**

d) apply mathematical reasoning, explaining and justifying inferences and deductions, justifying arguments and solutions

e) identify exceptional or unexpected cases when solving statistical problems

f) explore connections in mathematics and look for relationships between variables when analysing data

g) recognise the limitations of any assumptions and the effects that varying the assumptions could have on the conclusions drawn from data analysis.

**2: Specifying the problem and planning**

Students should be taught:

a) see that random processes are unpredictable

b) identify key questions that can be addressed by statistical methods

c) discuss how data relates to a problem; identify possible sources of bias and plan to minimise it

d) identify which primary data they need to collect and in what format, including grouped data, considering appropriate equal class intervals; select and justify a sampling scheme and a method to investigate a population, including random and stratified sampling

e) design an experiment or survey; decide what primary and secondary data to use.

**3: Collecting data**

Students should be taught:

a) collect data using various methods, including observation, controlled experiment, data logging, questionnaires and surveys

b) gather data from secondary sources, including printed tables and lists from ICT-based sources

c) design and use two-way tables for discrete and grouped data

d) deal with practical problems such as non-response or missing data.

**4: Processing and representing data**

Students should be taught:

a) draw and produce, using paper and ICT, pie charts for categorical data, and diagrams for continuous data, including line graphs (time series), scatter graphs, frequency diagrams, stem-and-leaf diagrams, cumulative frequency tables and diagrams, box plots and histograms for grouped continuous data

b) understand and use estimates or measures of probability from theoretical models, or from relative frequency

c) list all outcomes for single events, and for two successive events, in a systematic way

d) identify different mutually exclusive outcomes and know that the sum of the probabilities of all these outcomes is 1

e) find the median, quartiles and interquartile range for large data sets and calculate the mean for large data sets with grouped data

f) calculate an appropriate moving average

g) know when to add or multiply two probabilities: if A and B are mutually exclusive, then the probability of A or B occurring is P(A) + P(B), whereas if A and B are independent events, the probability of A and B occurring is P(A) $\times$ P(B)

h) use tree diagrams to represent outcomes of compound events, recognising when events are independent

i) draw lines of best fit by eye, understanding what these represent

j) use relevant statistical functions on a calculator or spreadsheet.

**5: Interpreting and discussing results**

Students should be taught to:

a) relate summarised data to the initial questions

b) interpret a wide range of graphs and diagrams and draw conclusions; identify seasonality and trends in time series

c) look at data to find patterns and exceptions

d) compare distributions and make inferences, using shapes of distributions and measures of average and spread, including median and quartiles; understand frequency density

e) consider and check results, and modify their approaches if necessary

f) appreciate that correlation is a measure of the strength of the association between two variables; distinguish between positive, negative and zero correlation using lines of best fit; appreciate that zero correlation does not necessarily imply 'no relationship' but merely 'no linear relationship'

g) use the vocabulary of probability to interpret results involving uncertainty and prediction [for example, 'there is some evidence from this sample that ...']

compare experimental data and theoretical probabilities

h) understand that if they repeat an experiment, they may - and usually will - get different outcomes, and that increasing sample size generally leads to better estimates of probability and population parameters.